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Original Article

# The climate impact on female acute pyelonephritis in Taiwan: A population-based study

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ABSTRACT

*Objective:* Urinary tract infection (UTI) is the main reason of community-acquired infection which causes large losses in social economy. The individual as well as climate factors make changes on the incidence. Acute pyelonephritis (APN) is one of the most serious UTI in female. The object of our study is to analyze whether climate factors will have effect on the incidence of female APN in Taiwan.
*Materials and methods:* This study consisted of 14,568 female patients with APN from 2001 to 2013 in Taiwan and patients with repeated APN were excluded. The monthly climate data was collected from the Central Weather Bureau. The available monthly climate data included highest, lowest, and average level of temperatures, humidity, rainfall, total rain days, and sunshine hours.
*Results:* The total incidence of female APN was 23.44 each 10,000 populations. The incidence of APN was positively correlated with temperature ($r = 0.66$), sunshine hours ($r = 0.45$), rainfall ($r = 0.42$), rain days ($r = 0.29$), and humidity ($r = 0.23$) per month. There is the strongest correlation between the average monthly temperature and the incidence of APN ($\beta = 0.54$). The correlation with the incidence of APN was also followed by rain days ($\beta = 0.28$) and humidity ($\beta = 0.27$).
*Conclusion:* There is a significant expression on the incidence of female APN affected by seasonality and climate parameters. The monthly average temperature has the strongest correlation with female APN. The results of this research may facilitate the potential preventive strategies on female APN.


## Introduction

Urinary tract infection (UTI) is one of the important part of community-acquired infections [1]. The incidence of UTI may be as high as 0.7 per person-year in young females [2]. The estimated annual cost of community-acquired UTI is about $1.6 billion and is rising in USA [1,3]. Women, the elderly, sexual activity, diabetes, chronic catheterization, and urinary tract abnormalities are risk factors of UTI [4–6].

Acute pyelonephritis (APN) is the severe form of UTI that can cause symptoms from flank pain to life-threatening illness [7]. The complications of APN include chronic renal scarring, impairment of renal function, and sepsis [8–10].

The effect of environmental factors on human health is still unclear. Seasonal variations have been reported in some diseases such as myocardial infarction, cervical cancer and several infectious diseases with a respiratory mode of transmission [11]. The seasonal variation of the incidence of infectious diseases may cause from

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the epidemiology of the prevalent pathogens, changes in environmental and climate parameters, and alterations in human behavior. Although the previous study indicated that the seasonal fluctuation and climate parameters had a link with UTI [12,13], but there are no large-scale data for the Asia-Pacific area.

Our aim in this study is to evaluate the effect of climate variables on the incidence of APN by using a 14-year population-based cohort database in Taiwan and used a time series analysis design. The research will help us to enhance awareness on certain environmental issues, reduce the burden of disease by predicting factors of incidence of APN.

## Methods

### *Database*

The nationwide population-based database was from the National Health Insurance Research Database (NHIRD) which we linked in this study. There are about 23 million individuals in the registry. All medical claims data and registry files of contracted medical institutions, board-certified expert and beneficiaries were included in NHIRD for over 23 million enrollees which represents over 98% of the Taiwanese population. Accordingly, the NHIRD is probably one of the largest and most comprehensive population-based databases in the world.

The Longitudinal Health Insurance Database (LHID) 2000 comprises all the claim data of one billion individuals sampled from the year 2000. The Registry for Beneficiaries of the NHIRD contains the registration data of everyone who was the beneficiary of the National Health Insurance program in 2000–2013. The patients in the LHID2000 and the original NHIRD had no significant differences in the gender distribution ($\chi 2 = 1.74$, df $= 1$, $p = 0.187$). In our study, we used LHID2000 to analyze the relationship between APN and climate factors.

### *Climate data*

The climate data in this study were provided by Central Weather Bureau (CWB) and the climate data of the corresponding month was obtained from 27 weather stations which over the islands of Taiwan, Penghu, Kinmen, and Lienchiang. The temperature (measured in degree Celsius), relative humidity (recorded in percentage), total rainfall (measured in millimeters), total rain days (recorded in days), and total sunshine hours (recorded in hours) were all included in the monthly climate data. Moreover, we used 1-month mean value of climatic data collected from the 27 weather observation stations because of the reason that Taiwan is an island which total land area is under 36,200 km and locates in the Pacific Ocean.

### *Study subjects*

Female patients with the diagnoses of APN (ICD-9-CM codes 590.1, 590.10, 590.11, 590.80, and 590.81) who received either ambulatory care or casualty care in Taiwan between January 1, 2000, and December 31, 2013 were enrolled in this study. If a patient who visit more than one medical visit for APN during the study, only the first time visit was selected as the study sample. Patients who were diagnosed with APN before 2000 or lived in the administrative regions without CWB weather stations were excluded.

### *Statistical analysis*

Descriptive statistics of individual characteristics and climate factors were calculated by cross-tabulation and figures. Spearman's rank correlation was used to discuss the relationship between climate factors and monthly incidence rates of APN. We also used linear regression model to estimate the correlation between the monthly incidence rates and meteorological factors. All tests were two-sided, and an alpha value was 0.05 which reducing the risk of type I error. The data were prepared and the analyses were performed with SAS 9.2 software.

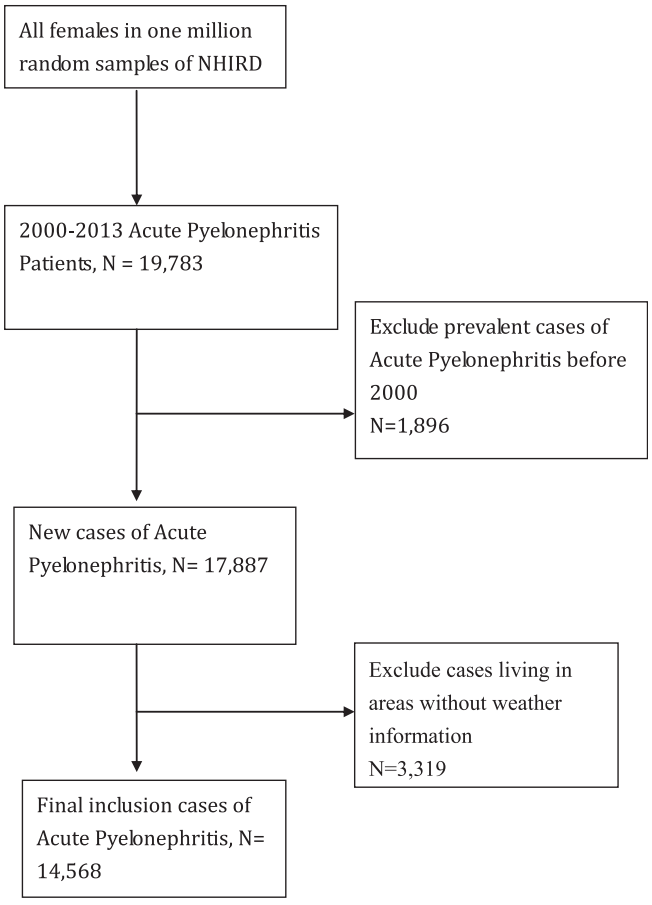


**Fig. 1.** Flowchart of recruitment of female patients of acute pyelonephritis from the 1-million random sample of the National Health Insurance Research Database (NHIRD) from 2000 to 2013 in Taiwan.

## Results

There were 484,931 female patients in the LHID2000, in which 14,568 patients were diagnosed of APN. We excluded patients who

**Table 1**
Demographic characteristics.

| Characteristics | Female gender N (%) |
|---|---|
| No. of cases | 14,568 |
| **Mean age (Standard deviation)** | 44.33 (18.67) |
| **Age at diagnosis** | |
| 20–29 | 2913 (20.00) |
| 30–39 | 2617 (17.96) |
| 40–49 | 2577 (17.69) |
| 50–59 | 2315 (15.89) |
| 60–69 | 1507 (10.34) |
| ≥70 | 1720 (11.81) |
| **Urbanicity** | |
| Urban | 5229 (35.89) |
| Suburban | 8116 (55.71) |
| Rural | 1186 (8.14) |
| Missing | 37 (0.25) |

had a diagnosis APN before the year 2000 (1896 patients) and patients without correlated the climate data (3319 patients). Finally, there are 14,568 candidates were enrolled in this study (Fig. 1). The demographic characteristics and medical conditions of enrolled patients are shown in Table 1. The average age of the female patients with APN was 44.33 ± 18.67 years old and a large proportion consisted of young and middle aged females (20–59 years old) (Table 1). The mean incidence of APN was 23.44 per 10,000 people.

In our primary study, the monthly APN incidence rate and its corresponding monthly climate data during the study period is shown in Fig. 2 which showed a correlation of APN incidence with high temperature, longer sunshine hours, high humidity degree, and larger rainfall amount. The average monthly incidence of APN and climate data in 13 years study period are according to the corresponding month in Table 2. The average temperature showed the similar pattern to the monthly incidence of APN with the highest (28.72 °C) in July and lowest (16.9 °C) in January. The highest monthly incidence of APN was July and followed by August and May. The correlation between the incidence of APN and climate factors is shown in Table 3. The temperature, sunshine hours, rain days, rainfall, and humidity had a positive correlation with the incidence of APN.

Average temperature ($\beta = 0.54$, $p < 0.001$), rain days ($\beta = 0.28$, $p < 0.01$), humidity ($\beta = 0.27$, $p < 0.01$), sunshine hours ($\beta = 0.04$,

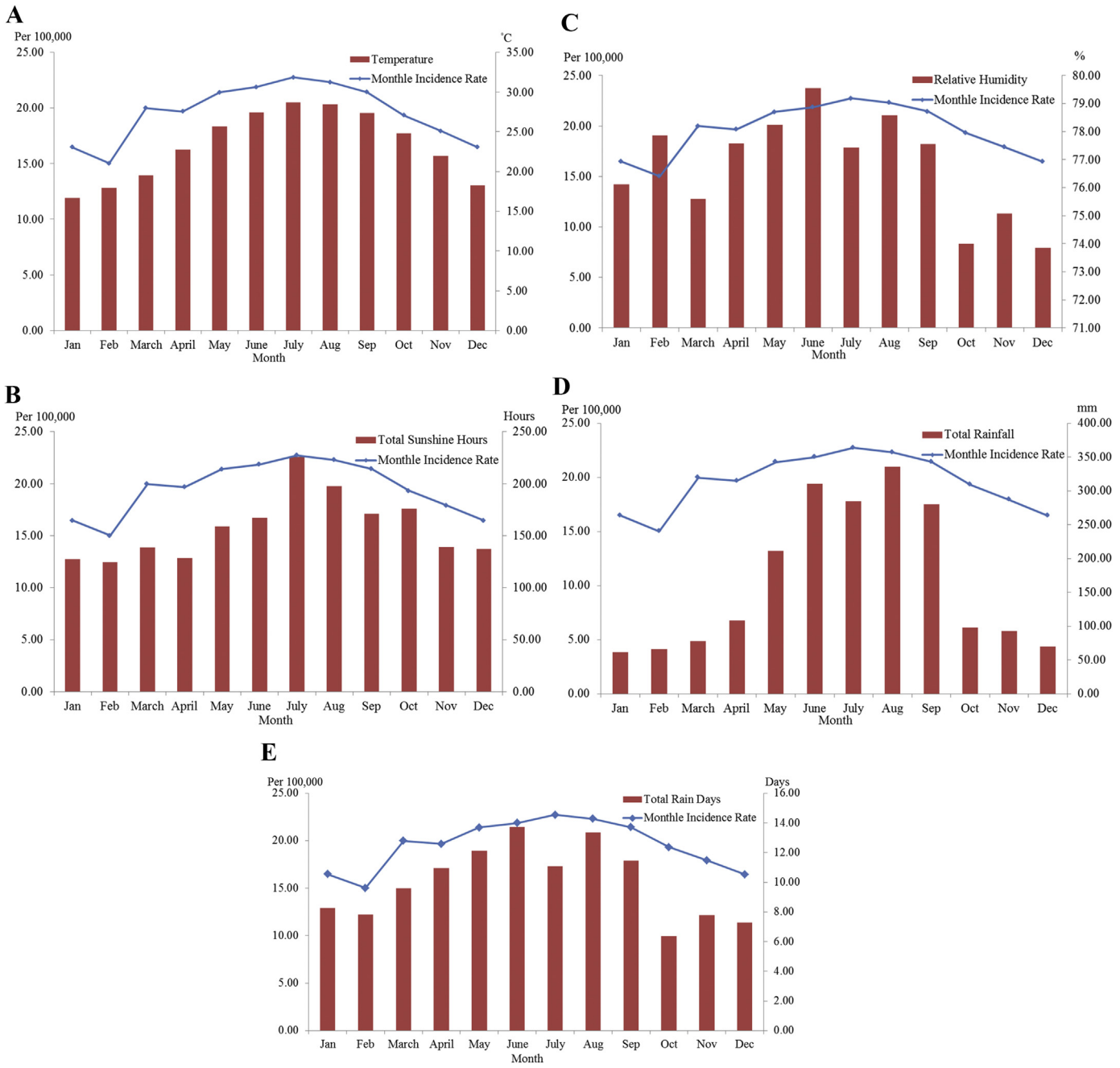


**Fig. 2.** The monthly incidence of APN and the corresponding monthly climate data during the study period. A. APN incidence of female and average ambient temperature (°C). B. APN incidence of female and monthly total sunshine hours (h). C. APN incidence of female and monthly relative humidity (%). D. APN incidence of female and monthly total rainfall (mm). E. APN incidence of female and monthly total rain days (days). APN = acute pyelonephritis.

**Table 2**
Average acute pyelonephritis incidence rate and climate factors according to monthly recorded.

| Month | Monthly Incidence Rate (per 100,000) | | Temperature (°C) | | | Total sunshine hours | Relative humidity (%) | Total rainfall (mm) | Total rain days |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | 95% CI | Mean | Max | Minimum | | | | |
| Jan | 16.47 | (15.07–17.88) | 16.90 | 21.90 | 10.60 | 128.48 | 75.95 | 62.23 | 8.29 |
| Feb | 15.02 | (13.21–16.84) | 18.17 | 23.50 | 10.80 | 125.81 | 77.64 | 66.78 | 7.78 |
| March | 19.98 | (17.81–22.15) | 19.79 | 24.30 | 12.80 | 139.23 | 75.42 | 77.97 | 9.50 |
| April | 19.67 | (17.86–21.48) | 22.94 | 26.80 | 17.10 | 128.83 | 77.24 | 108.26 | 10.84 |
| May | 21.40 | (19.14–23.66) | 25.86 | 28.70 | 20.50 | 160.26 | 77.85 | 213.51 | 12.09 |
| June | 21.87 | (20.56–23.18) | 27.52 | 29.80 | 21.60 | 167.20 | 79.31 | 315.79 | 13.80 |
| July | 22.74 | (21.35–24.12) | 28.72 | 30.80 | 22.50 | 223.84 | 77.14 | 291.61 | 11.28 |
| Aug | 22.31 | (22.31–24.12) | 28.48 | 30.10 | 22.30 | 196.28 | 78.31 | 347.25 | 13.52 |
| Sep | 21.43 | (20.04–22.82) | 27.39 | 30.00 | 21.20 | 171.50 | 77.44 | 283.08 | 11.52 |
| Oct | 19.33 | (17.68–20.97) | 24.92 | 28.00 | 19.00 | 175.30 | 73.97 | 101.41 | 6.51 |
| Nov | 17.93 | (16.86–18.99) | 22.06 | 25.60 | 16.90 | 139.00 | 75.03 | 95.65 | 7.87 |
| Dec | 16.46 | (14.89–18.03) | 18.41 | 22.90 | 11.60 | 137.63 | 73.73 | 71.05 | 7.39 |

**Table 3**
Crude correlations between climate factors and monthly acute pyelonephritis rates.

| Variable | Total |
|---|---|
| Temperature | 0.66*** |
| Total sunshine hours | 0.45*** |
| Relative humidity | 0.23** |
| Total rainfall | 0.42*** |
| Total rain days | 0.29*** |

* stands for P value<0.05.
** stands for P value<0.01.
*** stands for P value<0.001.

**Table 4**
Regression model of climate factors and monthly acute pyelonephritis rates.

| Variable | Total |
|---|---|
| Temperature | 0.54*** |
| Total sunshine hours | 0.04*** |
| Relative humidity | 0.27** |
| Total rainfall | 0.01*** |
| Total rain days | 0.28*** |

* stands for P value<0.05.
** stands for P value<0.01.
*** stands for P value<0.001.

$p < 0.001$), and rainfall amount ($\beta = 0.01$, $p < 0.001$) had a significant relationship with the incidence of female APN. Average temperature ($\beta = 0.54$, $p < 0.001$) had liner relationship with the incidence of female APN (Table 4).

## Discussion

Taiwan lies on the Tropic of Cancer and the west-pacific area and the climate of Taiwan is Marine Subtropical or Tropical which is divided by the Tropic of Cancer. Our study indicate that higher temperature, more monthly sunshine-hours, higher humidity, longer rain days and more rainfall are associated with an increase in female APN incidence in the nation-wide area of Taiwan. Furthermore, temperature, rain days, and humidity had a significant linear relationship comparing with the overall incidence of female APN.

The incidence of female APN and age in this study were compatible with previous studies [14–16]. The incidence of female APN was 23.44 per 10,000 populations. It was a little bit higher than United States (15–17 per 10,000 populations) [15] and lower than Korea (59.0 per 10,000 population) [17] in previous studies. The incidence of APN usually happened in young women. The peak of APN in young women was related to contraceptive use, pregnancy and sex [6,16].

Seasonal trend especially in summer have been noted in several studies of APN [14,17]. Ki et al. advanced studies from 1997 to 1999 that the incidence of APN has the highest peak in the summer for both women and men [17]. But such seasonal variation in UTI incidence hasn't been well explained. Seasonality may dependent on the changing of host behavior, environment or microbial pathogen factors [12,17,18]. The lower bacterial activity and the reducing virulence in winter could be one of the reasons of seasonality. The uropathogenic *Escherichia coli* which is the most common pathogen of APN was transmitted directly by person by person and acquired from the contaminated food or water with a seasonal pattern [19,20].

Temperature may be the most important factor in which may influence the seasonality in APN. First, the increased temperature enhances perspiration then causes body water loss, relative dehydration and leads to more concentrated urine and less frequent voiding [21]. A hot environment may cause a decrease in effective blood volume due to the peripheral vasodilation and pooling of blood in the skin. In contrast, exposure to cold environment may modify vasopressin and increase the amount of urine to facilitate the clearance of bacterial contaminants of the urinary tract [22]. The hot weather and increasing of monthly sunshine-hours may also cause more sweating and more moisture over the perineal area which may lead to the transferring of bacterial from the rectum to the urethra in females. Furthermore, the longer water residence times and increased rainfall extend the disease in wet regions due to a dilution effect [23] causing bacteria to invade the urethra or colonize more easily then eventually cause UTI.

There are several limitations in our study. The APNs was recognized by the ICD-9-CM coding system. The urine culture data is not available in NHIRD. The retrospective studies of the limitations about climate aspects should also be considered. Some of the factors are also not available in our database include habits that influenced dietary and lifestyle and specifically Taiwanese seasonal tastes.

In spite of these limitations, we figured out a significant association between the incidence of APN and temperature, sunshine hours, seasonality, rain days, rainfall and humidity. Our study may help in the design and institution of specific public health preventive measures, such as the need to consume more water and avoid exposure to heat in warm and wet weather. This becomes more important for female who is easily influenced by climatic conditions.

In conclusion, the seasonality and climate factors significantly affect the incidence of female APN in Taiwan. The data of this study

also indicates the influence of environmental factors on the incidence of APN which monthly average temperature, rain days, and humidity were strongest correlation with female APN. The results of this study may remind clinicians to be more attentive on the development of APN in female patients in rainy and hot months.

## Conflicts of interest

The authors declare that they have no conflicts of interest.

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